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SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION



Technology Demonstration Summary

SoilTech ATP Systems, Inc. Anaerobic Thermal Processor Waukegan Harbor Superfund Site Waukegan, Illinois

The SoilTech Anaerobic Thermal Processor (ATP) was evaluated under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) program. The SoilTech ATP technology was demonstrated at the Waukegan Harbor Superfund site in Waukegan, Illinois, in June 1992. The ATP technology is designed to thermally desorb organic compounds such as polychlorinated biphenyls (PCB) from soil, sediment, and sludge.

The ATP system removed about 99.98 percent of the PCBs from the soil and sandy sediment treated during the SITE demonstration. The PCB concentration in the treated solids was about 2 milligrams per kilogram (mg/kg). The stack gas contained an average of 0.8 micrograms per dry standard cubic meter ($\mu\text{g}/\text{dscm}$) of PCBs, resulting in destruction and removal efficiencies (DRE) for PCBs of greater than 99.9999 percent. Tetrachlorinated dibenzofuran (TCDF) was detected in the contaminated soil and sediment, treated solids, and stack gas. During the demonstration, the removal efficiencies

for TCDF exceeded 90 percent, and the DREs ranged from 99.99984 to 99.99994. No major operational problems affecting the ATP's ability to treat the contaminated soil and sediment were observed. The total cost to remediate 12,755 tons of contaminated soil and sediment at the Waukegan Harbor Superfund site was \$3,374,000.

This summary was developed by EPA's Risk Reduction Engineering Laboratory in Cincinnati, Ohio, to announce key findings of the SITE program demonstration. This demonstration is fully documented in two separate reports (see the ordering information at the end of this summary).

Introduction

The SITE program was established in 1986 to accelerate the development, demonstration, and use of new, innovative technologies that offer permanent cleanup solutions for hazardous wastes. One component of the SITE program is the demonstration program, which develops reliable engineering, performance, and cost data for innovative treatment technologies.



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Thus, the SITE demonstration program enables potential users to evaluate each technology's applicability to a specific waste site.

The SoilTech ATP technology was demonstrated at the Waukegan Harbor Superfund site in Waukegan, Illinois. The SITE demonstration was conducted during full-scale remediation of the site. The technology demonstration had the following primary objectives:

- Assess the technology's ability to remove PCBs from soil and sediment at the Waukegan Harbor Superfund site
- Determine whether PCBs are transformed to polychlorinated dibenzo-p-dioxins (PCDD) or polychlorinated dibenzofurans (PCDF) in the ATP system
- Document the operating conditions of the ATP technology and identify potential operational problems
- Determine capital and operating costs of the ATP technology

Technology Description

The ATP technology developed by SoilTech ATP Systems, Inc., thermally desorbs organic compounds such as PCBs from soil and sediment. The SoilTech ATP is a transportable treatment unit used for on-site remediation. It is a commercial plant designed to process 10 tons per hour (tph) of waste with the following characteristics: 5 to 10 percent moisture content; up to 10 percent hydrocarbon content; a pH between 5 and 11; and particle size of less than 2.5 inches in diameter. Wastes containing up to 20 percent moisture and 15 percent hydrocarbons can be treated without pretreatment. However, wastes with more than 20 percent moisture content require dewatering or blending with treated or inert solids to improve process economics; solids with more than 15 percent hydrocarbon content may require blending with treated solids or other wastes with lower concentrations of hydrocarbons before treatment.

The ATP system is composed of five main process units, which are discussed below. Figure 1 is a process flow diagram of the ATP's operations.

Feed System

The feed system consists of two feed hoppers and a conveyor belt. Contaminated solids are introduced from one feed hopper into the preheat zone of the ATP via the

conveyor belt. The second feed hopper contains clean sand that is fed to the ATP during startup and shutdown. Sand is also fed to the ATP during normal operations if the waste feed has inadequate inert soil; the sand acts as a heat carrier.

Anaerobic Thermal Processor

The SoilTech ATP is a proprietary process vessel that uses elevated temperatures to (1) remove volatile and semivolatile contaminants from soil and sediment and (2) isolate and concentrate the contaminants in a liquid phase in the vapor recovery system for proper and permanent disposal. The ATP is a horizontal, rotary kiln that contains four separate internal sections: the preheat, retort, combustion, and cooling zones. Figure 2 is a simplified sectional diagram showing the four internal zones.

The feed enters the ATP through the preheat zone. The preheat zone heats and mixes the feed at temperatures of 400 to 1,000 °F (depending on the contaminant type and concentration) to vaporize materials with relatively low boiling points, such as water, volatile organics, and some semivolatile organics. The remaining hot solids pass through a proprietary sand seal that continuously conducts them into the retort zone while almost totally preventing vapor flow. The retort zone operates at temperatures of 1,100 to 1,300 °F, which are high enough to vaporize heavy oils. Thermal cracking of hydrocarbons also takes place in the retort zone, resulting in formation of coke and gases of low molecular weight. The coked and decontaminated solids pass through a second sand seal into the combustion zone. The residence time for the solids in the preheat zone is typically about 30 minutes, and the residence time for the solids in the retort zone is 4 to 7 minutes, which is usually sufficiently long to ensure complete volatilization of the hydrocarbons.

The vapors and gases from the preheat and retort zones enter condensing systems, the two independent condenser trains shown in Figure 1. Most of each vapor and gas stream is condensed to liquid water and oils. The residual vapors, mainly noncondensable gases, are drawn out of the condensing systems and into the combustion zone of the ATP through the stationary end frame.

Two auxiliary burners are mounted in the stationary end frame of the ATP. These

burners are fired with natural gas and any combustible vapors in the remaining noncondensable off-gas stream to provide process heat.

The elevated temperature in the retort zone is achieved by recycling a portion of the hot, decontaminated solids from the combustion zone to the retort zone via a dedicated recycle channel.

The combustion zone contains lifters that lift the coked solids and discharge them in sheets that drop vertically through the horizontally moving air and flue gas stream. These falling solids are turbulently exposed to any oxygen present in the air stream, thus allowing combustion of the coke at the same time as the burning of the makeup fuels. The combustion zone temperature is maintained at 1,300 to 1,500 °F, depending on the amount of heat required to completely volatilize the contaminants in the retort zone. The residence time for the solids in the combustion zone is 10 to 20 minutes.

The solids in the combustion zone that are not diverted for recycling enter the cooling zone. Here they are lifted and distributed to the exterior of the kiln's inner shell to provide conductive heat transfer to the feed in the preheat zone. The treated solids are cooled to an exit temperature of 500 to 600 °F.

Finally, the treated solids drop from the ATP annulus into a screw conveyor beneath the sealed, stationary, feed-end plenum. The flue gases exit the top of the plenum and enter the flue gas treatment system.

Vapor Recovery System

The vapor recovery system cools and condenses water and contaminant vapors that are removed from the preheat and retort zones of the ATP. The vapors from the preheat zone are withdrawn under a vacuum to a preheat vapor recovery system consisting of a cyclone, condenser, and 3-phase separator. The fines collected in the preheat vapor cyclone are returned to the contaminated feed stream just before it enters the ATP.

The vapor stream from the retort zone first passes through a pair of cyclones to remove entrained particles; these particles, consisting of dusts and fines, are collected in a bin. The vapor is then cooled by oil circulating in two packed columns, the vapor scrubber and the fractionator. These columns act as a two-stage, direct-contact condenser for compounds with relatively high boiling points. For feed that contains

little or no heavy oil fraction, a charge of diesel or fuel oil may be added to provide a direct-contact condensing medium. At startup, oils are added to the vapor recovery system to provide circulation and reflux oils.

The vapor stream from the preheat zone and the uncondensed retort vapors are cooled to near-ambient temperatures in separate, water-cooled condensers. The three immiscible phases exiting each condenser are segregated in a gas-oil-water separator. The final noncondensable gas phase, consisting of light hydrocarbons (mostly butane and lighter compounds) and some inert gases (including carbon dioxide and nitrogen), is recycled to the combustion zone, where the hydrocarbons are oxidized. The liquid hydrocarbon phase in each separator is combined with the condensate from the packed columns. Bottom oil is periodically discharged to a waste oil storage tank. Condensed water is pumped directly to an on-site wastewater treatment system.

Flue Gas Treatment System

The flue gas treatment system removes particulates and trace hydrocarbons from the flue gas exiting the combustion zone of the ATP. All natural gas fuel and flammable off-gas noncondensable fractions are burned in the combustion zone within the stationary end frame of the ATP. The flue gas is treated in the flue gas treatment system before its release to the atmosphere. The flue gas first passes through a cyclone, which removes coarse dust, and then enters the baghouse, which removes fine dust; the dust collected by the cyclone and baghouse is removed via a screw conveyor and mixed with the treated solids. From the baghouse, the flue gas first passes through an acid gas scrubber to neutralize acid gases and then through an activated carbon unit to remove trace hydrocarbons. The acid gas scrubber may be taken off line and filled with activated carbon to provide additional adsorption capacity in order to improve the treatment system's hydrocarbon removal efficiency.

This was done at the Waukegan Harbor Superfund site.

Tailings Handling System

The tailings handling system quenches treated solids from the ATP and transports them to a storage pile. The treated solids (tailings) exiting the cooling zone of the ATP are quenched with process water and scrubber water; the water also serves to control dust. The tailings are then transported to an outside storage pile via screw and belt conveyors.

Demonstration Procedures

The SoilTech ATP technology was demonstrated at the Waukegan Harbor Superfund site in June 1992. The ATP technology began operating at the site in January 1992 to treat 12,755 tons of soil and sediment under a consent decree signed by EPA, the Illinois Environmental Protection Agency, and the responsible

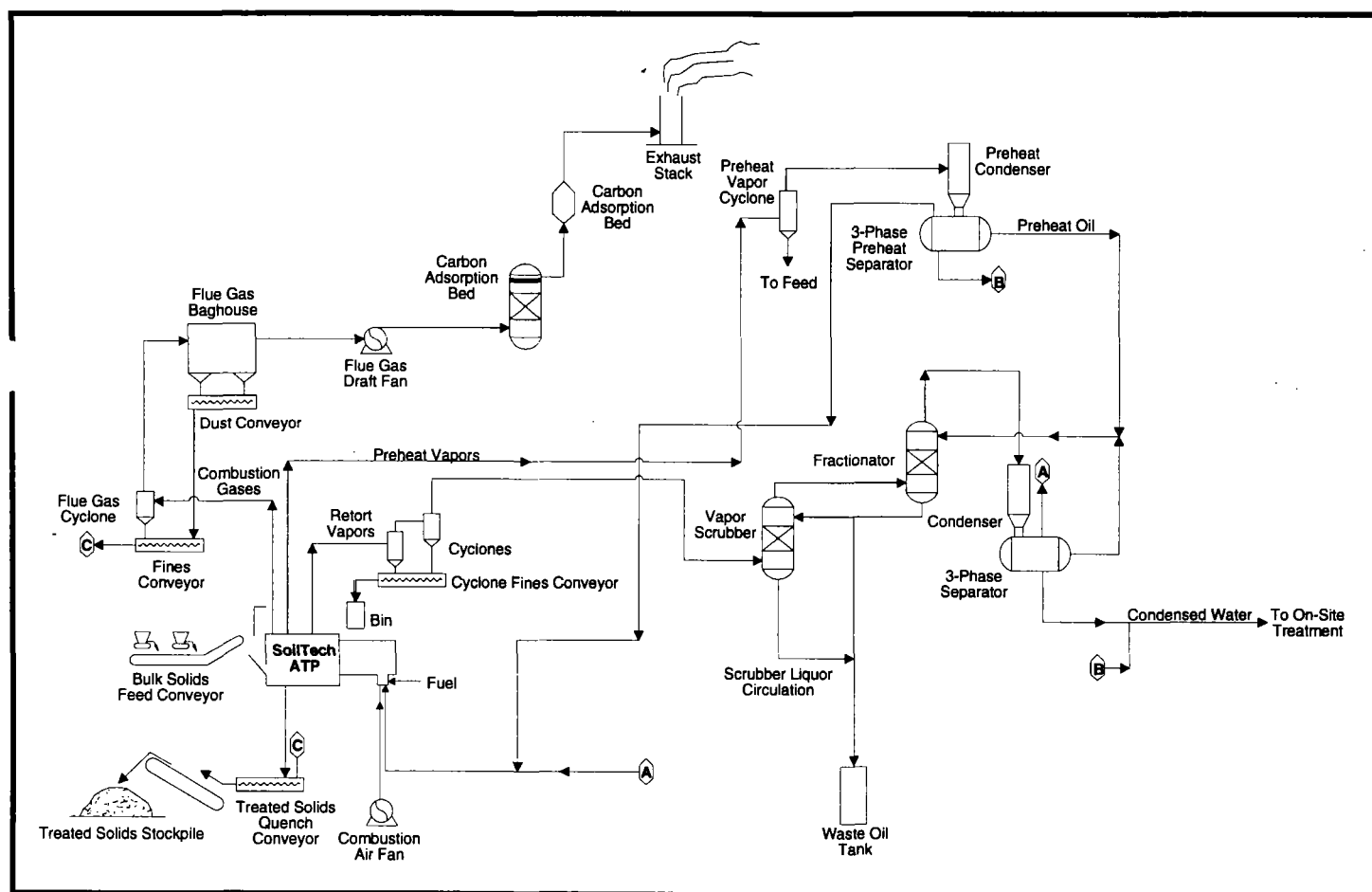


Figure 1. Simplified process flow diagram.

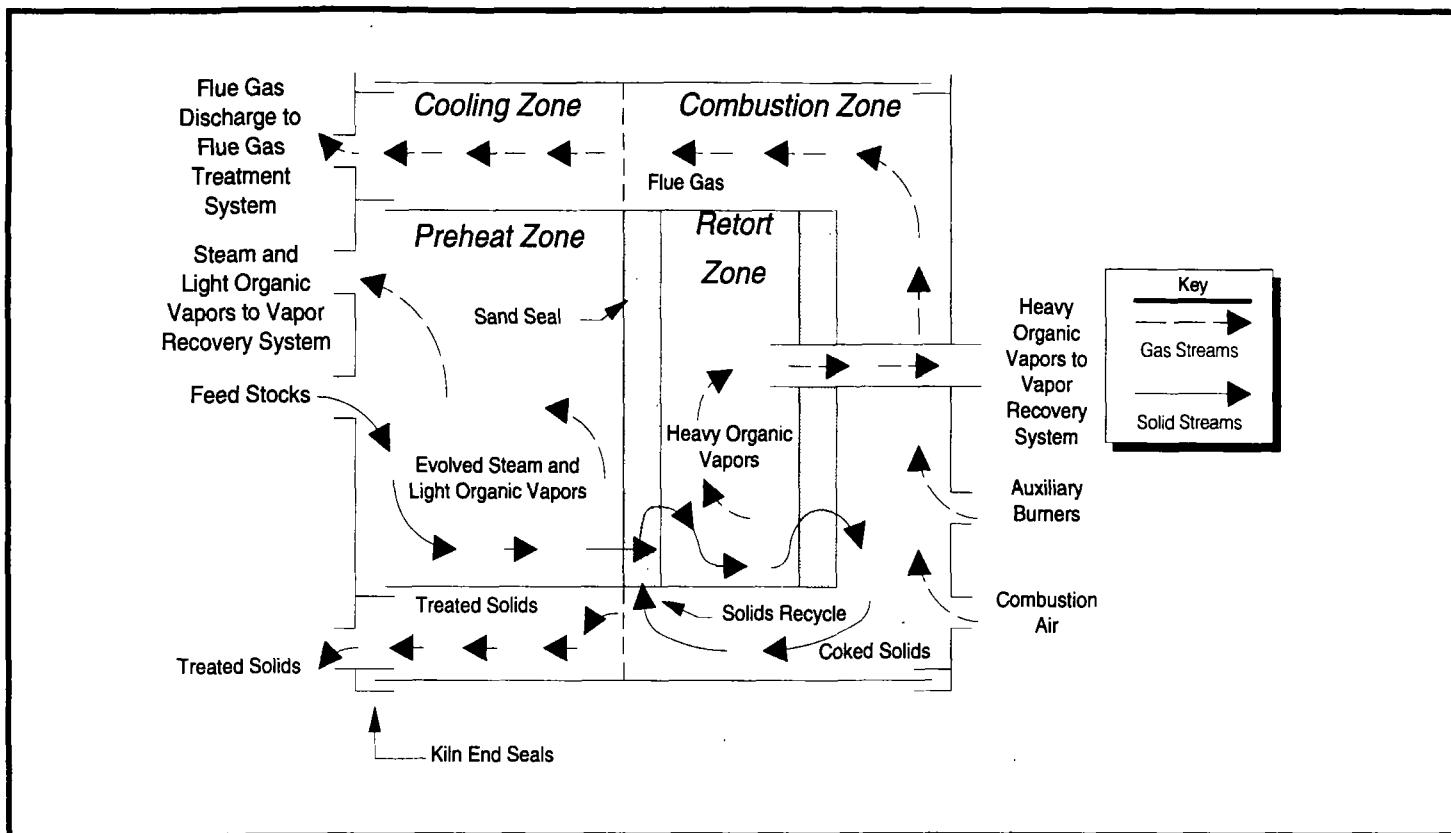


Figure 2. Simplified sectional diagram showing the four internal zones.

parties. During the SITE demonstration, about 253 tons of PCB-contaminated soils and sediments was fed to the ATP at 8.3 tph during four test runs of the ATP system. The ATP was run under two sets of operating conditions. First, three replicate test runs were conducted under the operating conditions used to remediate the site. After the third replicate test run, SoilTech stopped adding sodium bicarbonate to the ATP; the sodium bicarbonate had been added to reduce emissions of PCBs from the stack. A fourth test run was then conducted.

Each of the first three test runs included 8.5 hours of solids and liquids sampling and 8 hours of stack gas sampling. The solids and liquids sampled during each run were (1) contaminated soil and sediment, (2) treated solids, (3) flue gas cyclone fines and baghouse dust, (4) retort vapor cyclone fines, (5) condensed water before treatment, (6) waste discharge oil, and (7) preheat oil. Stack gases and noncondensable off-gases from the preheat and retort zones of the ATP were also sampled during each run.

Solid, liquid, and stack gas samples were analyzed for the following critical parameters: PCBs, dioxins, and furans. Samples were also analyzed for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and noncritical chemical and physical parameters to characterize the contaminated soil and sediment, treated solids, internal process streams, and stack gas.

The fourth test run included 4.25 hours of solids and liquids sampling and 4 hours of stack gas sampling. The media sampled were (1) contaminated soil and sediment, (2) treated solids, (3) flue gas cyclone fines and baghouse dust, (4) waste discharge oil, and (5) stack gas. Samples collected during the fourth test run were analyzed only for critical parameters (PCBs, dioxins, and furans).

Demonstration Results

The demonstration results are based on the observations of SITE personnel during system operation as well as extensive laboratory analyses. The following sections

discuss (1) PCB removal, (2) PCDD and PCDF results, (3) VOC and SVOC removal, (4) metals results, (5) general chemical results, (6) physical properties results, (7) operational problems, and (8) the costs of using the ATP system at the Waukegan Harbor Superfund site.

PCB Removal

During the demonstration, contaminated soil and sediment and treated solids were sampled and analyzed for PCBs to determine the ATP technology's ability to remove PCBs from the soil and sediment. Table 1 presents the concentrations of total PCBs in the contaminated soil and sediment and the treated solids. For the first three test runs, the average total PCB concentration was reduced from 9,670 mg/kg in the contaminated soil and sediment to 2.0 mg/kg in the treated solids, a 99.98 percent average removal efficiency. During the fourth test run, the total PCB concentration was reduced from 12,241 mg/kg in the contaminated soil and sediment to 1.7 mg/kg in the treated solids, a 99.99 percent removal efficiency.

Table 1. PCB Removal Efficiency.

Test Run No.	Total PCB Concentration (mg/kg)		Percent Removal
	Contaminated Soil and Sediment	Treated Solids	
1	10,158	1.45	99.986
2	8,673	2.65	99.969
3	10,180	1.90	99.981
Average — Test runs 1–3	9,670	2.00	99.979
4	12,241	1.69	99.986

The removal efficiencies for each of the congener groups were approximately equal, indicating that the more chlorinated PCBs were as effectively removed as the less chlorinated PCBs. These data show that the ATP technology removed PCBs from the soil and sediment to the extent that residual concentrations were below the site action levels of (1) 500 mg/kg and (2) greater than 97 percent removal efficiency.

The DRE was used to compare the amount of PCBs in the stack gas to the amount of PCBs fed into the ATP system. The percent DRE is expressed by the following equation:

$$DRE = \frac{(Mass)_{In} - (Mass)_{Out}}{(Mass)_{In}} \times 100$$

where,

$(Mass)_{In}$ = Mass of PCBs in contaminated soil and sediment

$(Mass)_{Out}$ = Mass of PCBs in the stack gas

The DREs for each test run are presented in Table 2. The DREs for the first three replicate test runs range from 99.99987 to 99.999990 percent. The ATP system achieved a DRE of 99.999996 percent during the fourth test run. These DREs exceed the standard for incinerators regulated under the Toxic Substances Control Act of 99.9999 percent.

Table 3 provides the PCB analytical results for the internal process streams for the first three test runs. The PCB concentrations in the retort vapor cyclone fines were generally about three times higher than those in the treated solids. This is likely due to the fact that PCBs adsorb preferentially to finer particles such as the retort vapor cyclone fines. Assuming that the PCB concentrations in the retort vapor cyclone fines provide a conservative estimate of the PCB concentrations in the solids in the ATP's retort zone, the relatively low residual concentrations of PCBs in the retort vapor cyclone fines indicate that most of the PCBs are removed in the preheat and retort zones of the ATP and not in the combustion zone. Of the internal liquid streams (condensed water, preheat oil, and waste discharge oil), the highest PCB concentrations were found in the waste discharge oil. The average PCB concentration in the waste discharge oil was about 290,000 mg/kg. This is to be expected because PCBs are more soluble in oil than in water. However, the condensed water and the preheat oil also contained significant concentrations of PCBs. The preheat and retort zone off-gases contained about 2.6 and 227 milligrams per dry standard cubic meter (mg/dscm) of PCBs, respectively.

PCDD and PCDF Results

During the SITE demonstration, samples of process effluents and internal process streams were collected and analyzed for dioxins and furans. In addition, samples of contaminated soil and sediment were collected and analyzed to document the types and concentrations of dioxins and furans fed to the ATP. The types of dioxins and furans in the contaminated soil and sediment were compared to the types in the process effluents and internal process streams to qualitatively and quantitatively evaluate whether (1) dioxins and furans were removed in the ATP process, or (2) PCBs were transformed to dioxins and furans. The concentrations of dioxins and furans detected in samples collected during the demonstration are presented in Table 4 and are discussed below.

Low levels of TCDF and pentachlorinated dibenzofuran (PeCDF) were present in the contaminated soil and sediment. TCDF was the only dioxin or furan congener detected in the treated solids. The average TCDF concentration in the treated solids was about 6 micrograms per kilogram ($\mu\text{g/kg}$), which is about one order of magnitude lower than the concentration in the contaminated soil and sediment.

Based on the analytical results for contaminated soil and sediment, treated solids, and stack gas samples, some of the PCDFs present in the contaminated soil and sediment were probably vaporized and removed from the contaminated soil and sediment in the ATP system. For the first three test runs, TCDF was the only dioxin or furan congener detected in the stack gas; it was detected at an average concentration of 0.0787 nanogram per dry standard cubic meter (ng/dscm).

Table 5 presents the DREs for TCDF, which is the only PCDD or PCDF

Table 2. PCB Destruction and Removal Efficiency.

Test Run No.	PCB Concentration in Contaminated Soil and Sediment (mg/kg)	Contaminated Soil and Sediment Feed Rate (tph of dry solids)	PCBs Fed to ATP (lb/hr)	PCB Concentration in Stack Gas (ng/dscm)	Stack Gas Flow Rate (dscfm)	PCBs Exiting Stack (lb/hr)	DRE (percent)
1	10,158	6.92	140.60	944	5,330	18.90×10^{-6}	99.9999866
2	8,673	7.89	136.87	687	5,520	14.27×10^{-6}	99.9999896
3	10,180	7.56	153.73	869	5,280	17.15×10^{-6}	99.9999889
Average— Test runs 1–3	9,670	7.46	143.73	833	5,377	16.77×10^{-6}	99.9999884
4	12,241	7.42	181.72	423	5,130	8.09×10^{-6}	99.9999955

Table 3. Average PCB Concentrations in Internal Process Streams During First Three Test Runs.

PCBs	Flue Gas Cyclone Fines and Baghouse Dust (mg/kg)	Retort Vapor Cyclone Fines (mg/kg)	Waste Discharge Oil (mg/kg)	Condensed Water (µg/L)	Preheat Oil (µg/L)	Preheat Off-gas (µg/dscfm)	Retort Off-gas (µg/dscfm)
Monochlorobiphenyls	0.0471	0.056	3,383	21,475	2,233	13	20,000
Dichlorobiphenyls	0.7021	0.445	27,667	75,667	11,800	150	53,000
Trichlorobiphenyls	2.996	1.268	77,000	111,750	22,167	630	70,000
Tetrachlorobiphenyls	7.829	3.572	138,333	99,667	18,833	1,400	68,000
Pentachlorobiphenyls	2.929	1.199	39,500	17,025	2,933	310	13,000
Hexachlorobiphenyls	0.4029	0.161	4,933	1,381	197	25	1,200
Heptachlorobiphenyls	0.0836	0.032	860	200	26 ^a	13	410
Octachlorobiphenyls	0.0139	< 0.006	350	< 30	32 ^a	13	320
Nonachlorobiphenyls	<0.0200	< 0.010	< 100	< 50	< 50	22	530
Decachlorobiphenyls	<0.0200	< 0.010	< 100	< 50	< 50	22	500
TOTAL ^b	15.01	6.746	292,116	327,230	58,266	2,598	226,960

Notes:

^a This analyte was detected at a concentration below the PQL.

^b During calculation of the total concentration, compounds not detected were assumed to be present at concentrations of 0.5, 0.4, 0.6, and 0.5 times the PQL for the first, second, third, and fourth nondetected compounds, respectively.

consistently detected in contaminated soil and sediment and in stack gas. The DREs ranged from 99.99984 to 99.99994 percent.

The concentrations of dioxins and furans in the flue gas cyclone fines and baghouse dust were about one order of magnitude higher than those in the retort vapor cyclone fines and were about the same as those in the contaminated soil and sediment. The flue gas cyclone fines and baghouse dust were blended with the treated solids.

TCDF and PeCDF were detected at the highest concentrations in the internal process streams. These are the same furan congeners as were detected in the contaminated soil and sediment. The highest furan concentrations were detected in the waste discharge oil. TCDF was the congener detected at the highest average concentration (135 µg/kg) during the first three test runs. TCDD, hexachlorinated dibenzofuran (HxCDF), and heptachlorinated dibenzofuran (HpCDF) were also detected at concentrations above the practical quantitation limit (PQL) in one or two replicate samples of various internal process streams.

The types of dioxins and furans in the contaminated soil and sediment were compared to the types in the process effluents and internal process streams to qualitatively and quantitatively evaluate whether PCBs were transformed to dioxins and furans. Low concentrations of furans

were present in the contaminated soil and sediment fed to the ATP and in the ATP's process effluents and internal waste streams. During the first three test runs, an average of about 104 µg/kg of furans were present in the contaminated soil and sediment and 6.1 µg/kg of furans were present in the treated soils. The stack gas contained 0.08 ng/dscm of furans. The dioxins and furans detected in the internal waste streams were either (1) the same congeners as were detected in the contaminated soil and sediment or (2) different congeners detected at concentrations below the contaminated soil and sediment detection limits. Therefore, the dioxins and furans detected in the internal waste streams may have been present in the contaminated soil and sediment at concentrations below the PQLs or may have been transformation by-products of PCBs.

VOC and SVOC Removal

During the demonstration, samples of contaminated soil and sediment, process effluents, and internal process streams were collected and analyzed for VOCs and SVOCs. Because VOCs and SVOCs were not present at high concentrations in the contaminated soil and sediment, no attempt was made to calculate the ATP's efficiency in removing VOCs and SVOCs.

The VOC analytical results indicate that xylenes, styrene, toluene, and chlorobenzene were present in the contaminated soil and sediment at average concentrations ranging from about 2 to 7 mg/kg; all other VOCs were detected at concentrations below 1 mg/kg. As expected, the VOCs were mostly removed in the ATP, and the treated solids contained low levels of VOCs. The total VOC concentration was reduced from about 17 mg/kg in the contaminated soil and sediment to 0.03 mg/kg in the treated soil.

Low concentrations of SVOCs, including dichlorinated and trichlorinated benzene compounds, di-n-octylphthalate, naphthalene compounds, and 3- and 4-methylphenol, were detected in the contaminated soil and sediment. The SVOC detected at the highest concentration was 2-methylnaphthalene at an average concentration of 13.1 mg/kg. The SVOCs in the contaminated soil and sediment were probably from oil discharged to the soil and sediment at the site. Only two SVOCs, bis(2-ethylhexyl)phthalate and N-nitrosodiphenylamine, were detected in the treated solids; both were detected at concentrations below the PQLs. No SVOCs were detected in the flue gas cyclone fines and baghouse dust. Naphthalene and several phenolic and phthalate compounds were present in the stack gas at concentrations below the PQLs.

Table 4. Average PCDD and PCDF Concentrations in Various Media for the First Three Test Runs.

Compound	Contaminated Soil and Sediment (µg/kg)	Treated Solids (µg/kg)	Flue Gas Cyclone Fines and Baghouse Dust (µg/kg)	Retort Vapor Cyclone Fines (µg/kg)	Waste Discharge Oil (µg/kg)	Condensed Water (µg/L)	Preheat Oil (µg/L)	Stack Gas (ng/dscm)
TCDD	<1.3	<2.4	0.17	<0.18	<1.4	0.049	<0.0061	<0.029
TCDF	88.17	6.05	149	14.9	135	1.57	0.383	0.0787
PeCDF	15.8	<1.8	17.83	3.45	14.5	0.097	0.045	<0.022
HxCDF	<2.7	<3.1	1.92	0.93	<1.5	-- ^a	0.004	<0.018
HpCDF	<4.4	<8.3	<0.41	0.23	<2.0	--	<0.011	<1.5
TOTAL ^b	103.97	6.05	168.92	19.51	149.5	1.716	0.432	0.0787

Notes:

- ^a -- = Compound was not detected: no PQL was determined because the surrogate spike compounds were not recovered due to large dilutions required for analysis.
- ^b Compounds not detected (designated as <PQL) were assigned a value of zero during calculation of the total concentrations.

Table 5. TCDF Destruction and Removal Efficiencies.

Test Run No.	TCDF Concentration in Contaminated Soil and Sediment (µg/kg)	Contaminated Soil and Sediment Feed Rate (tph of dry solids)	TCDFs Fed to ATP (lb/hr)	TCDF Concentration in Stack Gas (ng/dscm)	Stack Gas Flow Rate (dscfm)	TCDFs Exiting Stack (lb/hr)	DRE (percent)
1	100	6.92	1.38×10^{-3}	0.13	4,820	2.3×10^{-9}	99.99984
2	76.5	7.89	1.21×10^{-3}	0.040	4,780	7.2×10^{-10}	99.99994
3	88	7.56	1.33×10^{-3}	0.066	4,860	1.2×10^{-9}	99.99991
4	79	7.42	1.17×10^{-3}	<0.05	5,140	$<9.6 \times 10^{-10}$	99.99992

Metals Results

Although the ATP technology is not designed to treat wastes contaminated with metals, samples were analyzed to determine the metals concentrations in the contaminated soil and sediment and in the treated solids. The results of the metals analyses indicate that the contaminated soil and sediment and the treated solids contained similar concentrations of metals. This is to be expected because the ATP is not operated at temperatures high enough to volatilize most metals.

Samples of treated solids were also collected to determine the leachability of selected metals. The target parameters included the toxicity characteristic leaching procedure (TCLP) metal analytes. Arsenic and barium were detected in the TCLP extract from treated solids samples collected during the first three test runs at average concentrations of 0.038 and 0.127 milligram per liter (mg/L), respectively. The TCLP metals concentrations in all samples were below the regulatory limits.

General Chemical Results

General chemical analyses were performed to characterize the contaminated soil and sediment and the treated solids and to investigate whether the ATP process altered the characteristics of the soil. In addition, samples of stack gas were collected and analyzed to determine its general chemical characteristics.

The results of total recoverable petroleum hydrocarbon (TRPH) analyses indicate that the contaminated soil and sediment had a relatively high concentration of recoverable petroleum hydrocarbons. The TRPH concentration in the contaminated soil and sediment during the first three test runs averaged 3,003 mg/kg.

The results of total organic carbon (TOC), extractable organic halide (EOX), and total chlorides analyses indicate that the ATP removed the organic compounds from the contaminated soil and sediment; however, some of the halogenated organic compounds may have been dehalogenated. The average TOC

concentration was reduced from 16,000 mg/kg in the contaminated soil and sediment to 952 mg/kg in the treated solids. Similarly, the average EOX concentration was reduced from 1,900 mg/kg in the contaminated soil and sediment to less than 21.9 mg/kg in the treated solids. However, the average total chlorides concentration increased from 303 mg/kg in the contaminated soil and sediment to 1,073 mg/kg in the treated solids.

The average pH increased from 8.59 in the contaminated soil and sediment to 11.35 in the treated solids. The increase in pH was due to the sodium bicarbonate used during the first three test runs to reduce PCB emissions from the flue gas treatment system.

The stack gas contained low levels of particulate matter, hydrogen chloride, and hydrogen fluoride. The stack gas also contained low levels of calcium, iron, sodium, and strontium, all of which were detected in stack gas particulate matter. The average moisture content of the stack gas was 12.5 percent.

Table 6. Costs of ATP System Application at the Waukegan Harbor Superfund Site

Cost Category	Total Cost	Cost per Ton ^a
Site Preparation and Mobilization	\$655,000	\$51
Permitting and Regulatory	188,000	15
Capital Equipment	361,000	28
Startup	158,000	12
Labor	854,000	67
Supplies and Consumables	139,000	11
Utilities	65,000	5
Effluent Monitoring	207,000	16
Residual and Waste Handling and Transporting	186,000	15
Analytical Services	38,000	3
Equipment Repair and Replacement	133,000	10
Site Demobilization	390,000	31
TOTAL	\$3,374,000	\$264

Note:

a This is the cost for each ton of waste material treated at the site using the ATP, based on a total of 12,755 tons treated.

Physical Properties Results

Samples were collected and analyzed during the demonstration to characterize the physical properties of the contaminated soil and sediment and treated solids to assess the potential impact of treatment on disposal or placement of treated solids.

Moisture Content

The moisture content of the contaminated soil and sediment averaged 12.9 percent, which is within the acceptable range for soil and sediment treatment in the ATP system. The moisture content of the treated solids (after quenching) averaged 8.86 percent.

Density

The contaminated soil and sediment had higher maximum dry densities than the treated solids. Although no large changes in density were observed, analytical results suggest that thermal processing slightly changed the soil and sediment characteristics.

California Bearing Ratio (CBR)

The CBR values were determined as a function of dry density at 10, 25, and 56 blows per layer of treated solids sample. The analytical results indicate that the CBR values increased as a function of dry density. In the ATP, moisture is removed from the feed soil and is added to the treated solids for quenching. To optimize the dry density of the treated solids, water should be added so that the material is

brought close to the optimum moisture content.

Operational Problems

During initial testing at the Waukegan Harbor Superfund site, the ATP system had problems meeting the site-specific requirements of 99.9999 percent for the PCB DRE and 30 ng/dscm for total PCDD and PCDF emissions. Process modifications implemented in March 1992 resulted in improvements in the PCB DRE and the ATP stack emission results. The process modifications included the following:

- The carbon bed depth in the stack was increased to 24 inches.
- The acid gas scrubber was taken out of service and converted to an adsorption unit by the addition of activated carbon to the scrubber housing.
- Retort zone residence time was increased by reducing the amount of solids recycled from the combustion zone to the retort zone.
- Activated carbon beds were installed in the preheat and retort zone off-gas return lines to the burners.
- The burners were operated at maximum operating capacity to maintain the combustion zone temperature.
- Possible leaks in the granular activated carbon adsorption system were sealed.

These process modifications enabled the ATP system to meet the PCB DRE and PCDD and PCDF emissions requirements for the Waukegan Harbor Superfund site.

During the SITE demonstration, no operational problems were observed that affected the ATP system's ability to treat contaminated soil and sediment. SoilTech estimates that an on-line efficiency (mechanical availability) of 75 to 80 percent is typical for the system. This on-line efficiency could not be verified during the SITE demonstration because of the relatively short (4-day) duration of the demonstration.

Costs

Cost data on the use of the SoilTech ATP technology to remediate the Waukegan Harbor Superfund site were obtained from SoilTech. These data were placed in 12 cost categories typically evaluated for cleanup activities at Superfund and Resource Conservation and Recovery Act (RCRA) corrective action sites. The actual costs of ATP system application at the site form the basis for the costs presented in Table 6.

The cost data are based on treating 12,755 tons of PCB-contaminated soil and sediment at the Waukegan Harbor Superfund site. The permitting and regulatory support, site preparation and mobilization, startup, and demobilization costs for SoilTech's 10-tph unit totaled about \$1,400,000, and the treatment costs totaled about \$155 per ton of soil and sediment treated.

Costs may vary significantly depending on site-specific conditions, contamination of concern, and permitting and regulatory support requirements. SoilTech estimates ATP processing costs at \$120 to \$150 per ton of waste treated for large projects and at \$300 to \$600 per ton for small, specialized projects. A 5-tph, truck-mounted ATP unit is also available. For the 5-tph unit, fixed costs are expected to be lower, but soil treatment costs would be higher.

Conclusions

Based on the results of the SITE demonstration, the following conclusions were drawn regarding the SoilTech ATP technology:

- The ATP can remove organic contaminants such as PCBs and PCDFs from contaminated soil and sediment, resulting in low

concentrations in the treated solids. The primary contaminant removal mechanism is thermal desorption.

- Most contaminants removed from the waste are accumulated in the vapor scrubber oils in the vapor recovery system. Treatment residuals, including vapor scrubber oils, condensed water, and spent activated carbon, are not destroyed on site and require off-site treatment.
- PCB removal efficiency is not enhanced by adding sodium bicarbonate to the combustion zone of the ATP system.
- There is no conclusive evidence that PCBs are transformed to PCDDs or PCDFs in the ATP system.
- The ATP's flue gas treatment system can effectively meet stack gas emission standards for organic compounds.
- The ATP is a mechanically reliable system. No significant operational problems were observed that affected the ATP system's ability to treat contaminated soil and sediment. However, ATP process modifications were required during initial testing at the Waukegan Harbor Superfund site to improve the PCB DRE and to reduce PCDD and PCDF stack emissions.
- The ATP system may present a cost-effective means for treating wastes at Superfund and RCRA corrective action sites.

The EPA Project Manager, **Paul de Percin**, is with the Risk Reduction Engineering Laboratory, Cincinnati, OH 45268 (see below).

The complete report, entitled "Technology Evaluation Report: SITE Program Demonstration of the SoilTech ATP Systems, Inc. Anaerobic Thermal Processor at the Waukegan Harbor Superfund Site" (Order No. PB 91-XXX XXX/AS; Cost: \$XX.XX, subject to change) discusses the results of the SITE demonstration.

This report will be available only from:

National Technology Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

A related report, entitled "Applications Analysis Report: SoilTech ATP Systems, Inc. Anaerobic Thermal Processor at the Wide Beach Development Site and Waukegan Harbor Superfund Site," discusses the applications and costs of the ATP.

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